Propagating vs. Non-propagating MJO
(+ MJO in CMIP3 & CMIP5 models)

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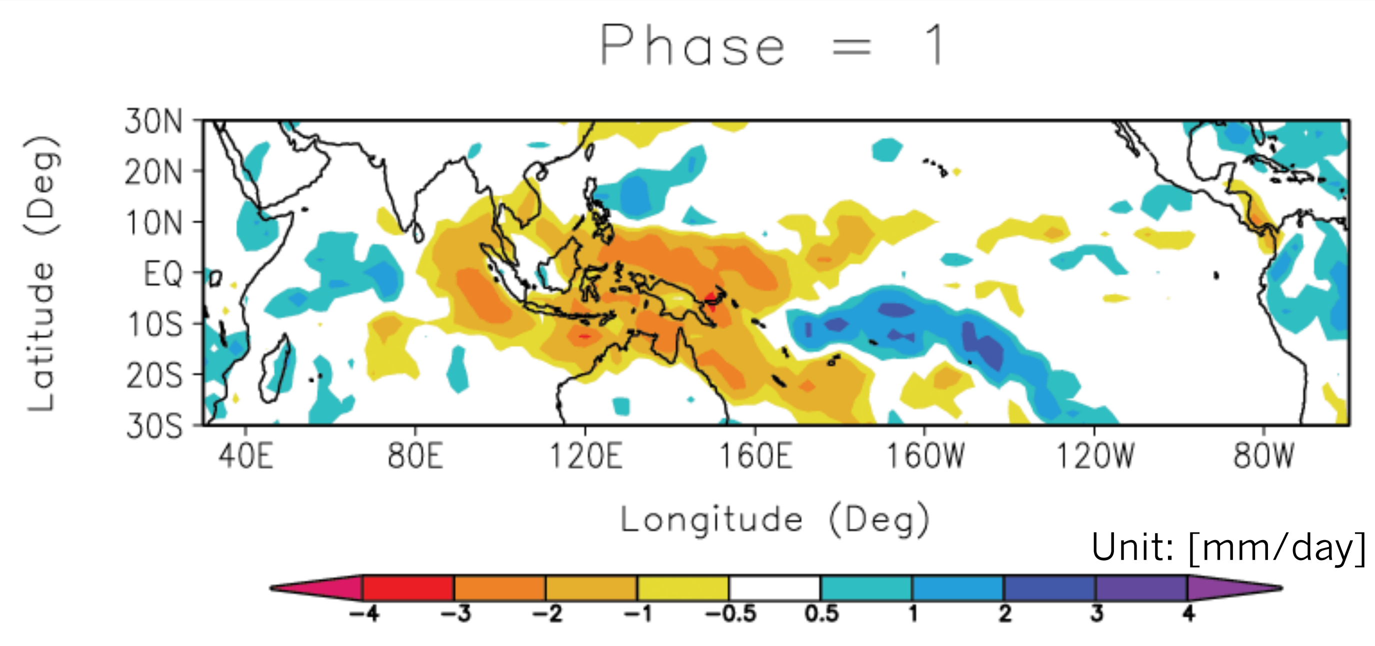
The Madden-Julian Oscillation

- An organized convection in the tropics which propagates eastward, with planetary scale and 30-60 day period

- Dominant intraseasonal (20-100 day) variability in the tropics

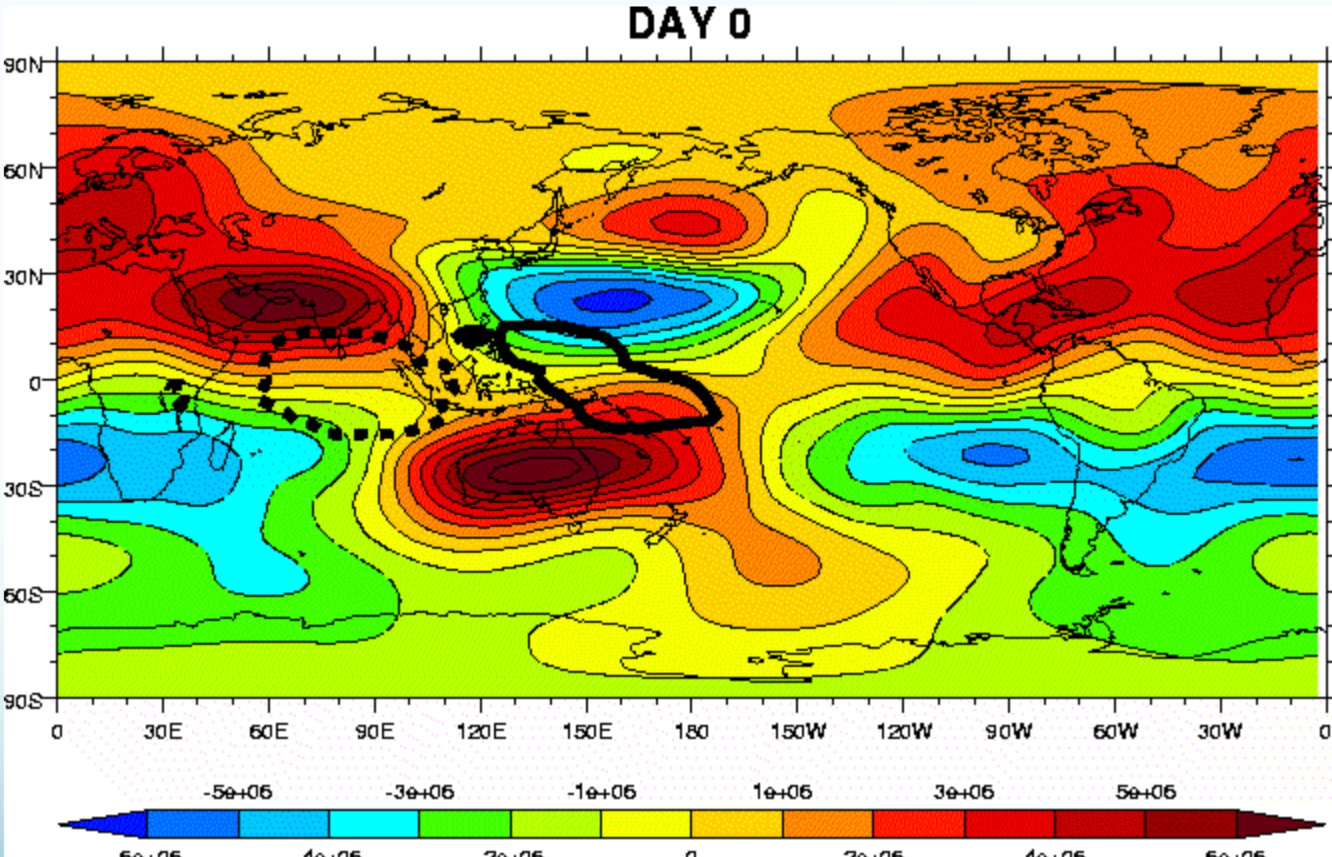
Anomalous precipitation associated with the MJO (TRMM, Nov-Apr)



*MJO index : leading modes PCs of combined EOF (15S-15N averaged, 20-100 day filtered OLR, U850, and U200)

Global Impacts of the MJO

200 hPa Streamfunction anomaly associated with the MJO

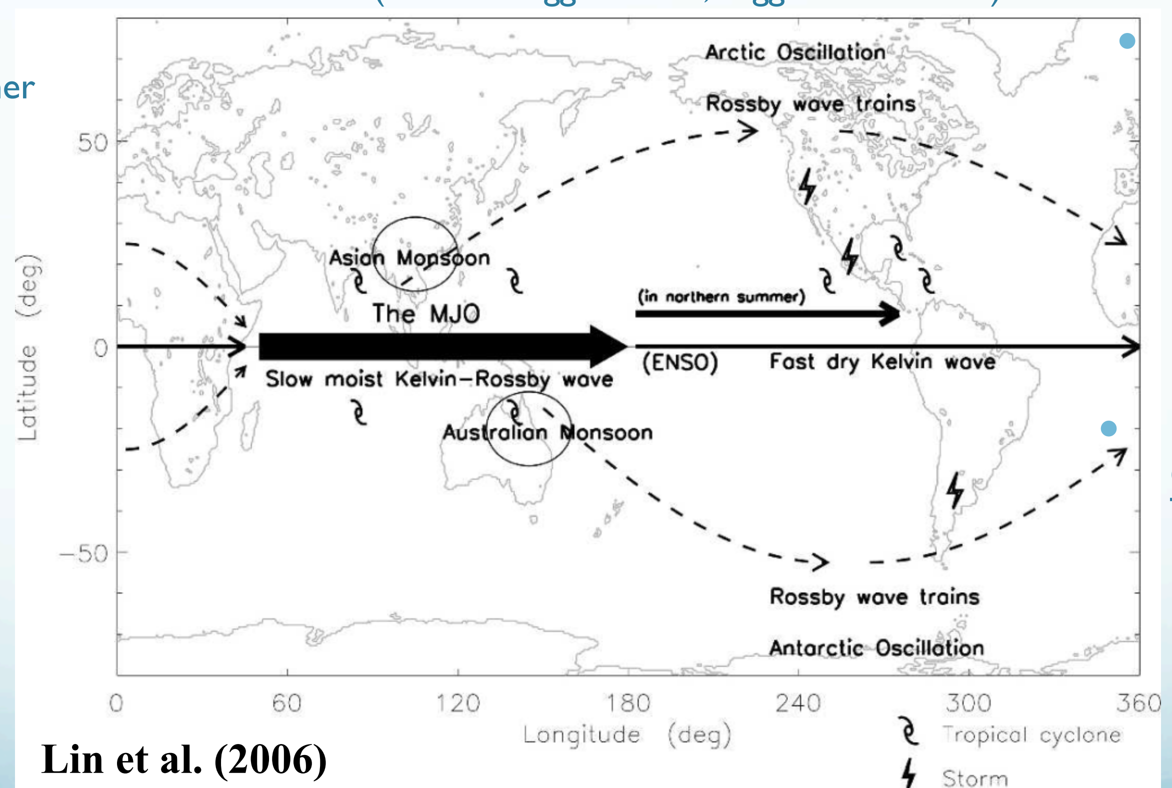


Contour (precip)
Solid: Positive
Dashed: negative

Source: http://envam1.env.uea.ac.uk/mjo.html

Why is the MJO important?

- Precipitation events in extratropics (Mo and Higgins 1998; Higgins et al. 2000)
- Indian and Australian summer monsoons (Yasunari 1979; Wheeler and McBride 2005)



Lin et al. (2006)

- Tropical cyclones in almost all basins (Liebmann et al. 1994; Maloney and Hartmann 2001a)
- Some El Niño events (Kessler et al. 1995; Takayabu et al. 1999; Bergman et al. 2001)
- Arctic Oscillation and Antarctic Oscillation (Miller et al. 2003; Carvalho et al. 2005).

Why is the MJO important? - part 2

It bridges the 'predictability gap'

this, next week (7~14 day)
: weather forecast
*Source of predictability - initial condition

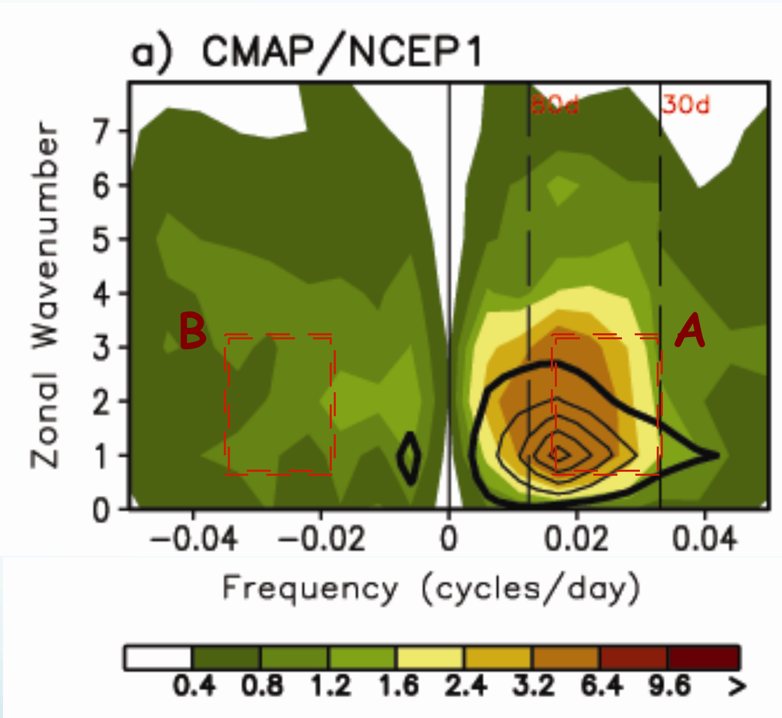
: intra-seasonal prediction
*Source of predictability - Madden-Julian Oscillation

next season (1~6 month)
: seasonal prediction
*Source of predictability - ENSO

A Very Brief Introduction to the MJO

- Has planetary scale, 30-60 day period, eastward propagation
- Interacts with a wide variety of weather and climate phenomena globally by modulating tropical convection
- Provides the source of predictability in intra-seasonal time scale, bridging the 'predictability gap' between weather and seasonal prediction

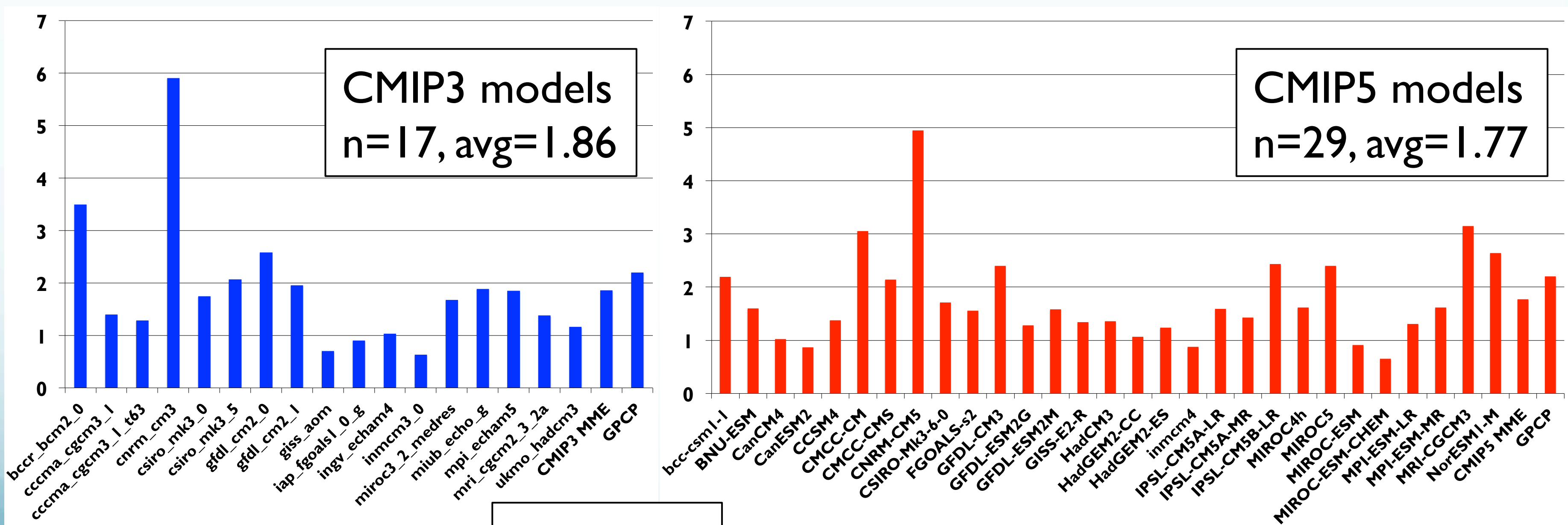
MJO metric from wavenumber-frequency power spectrum



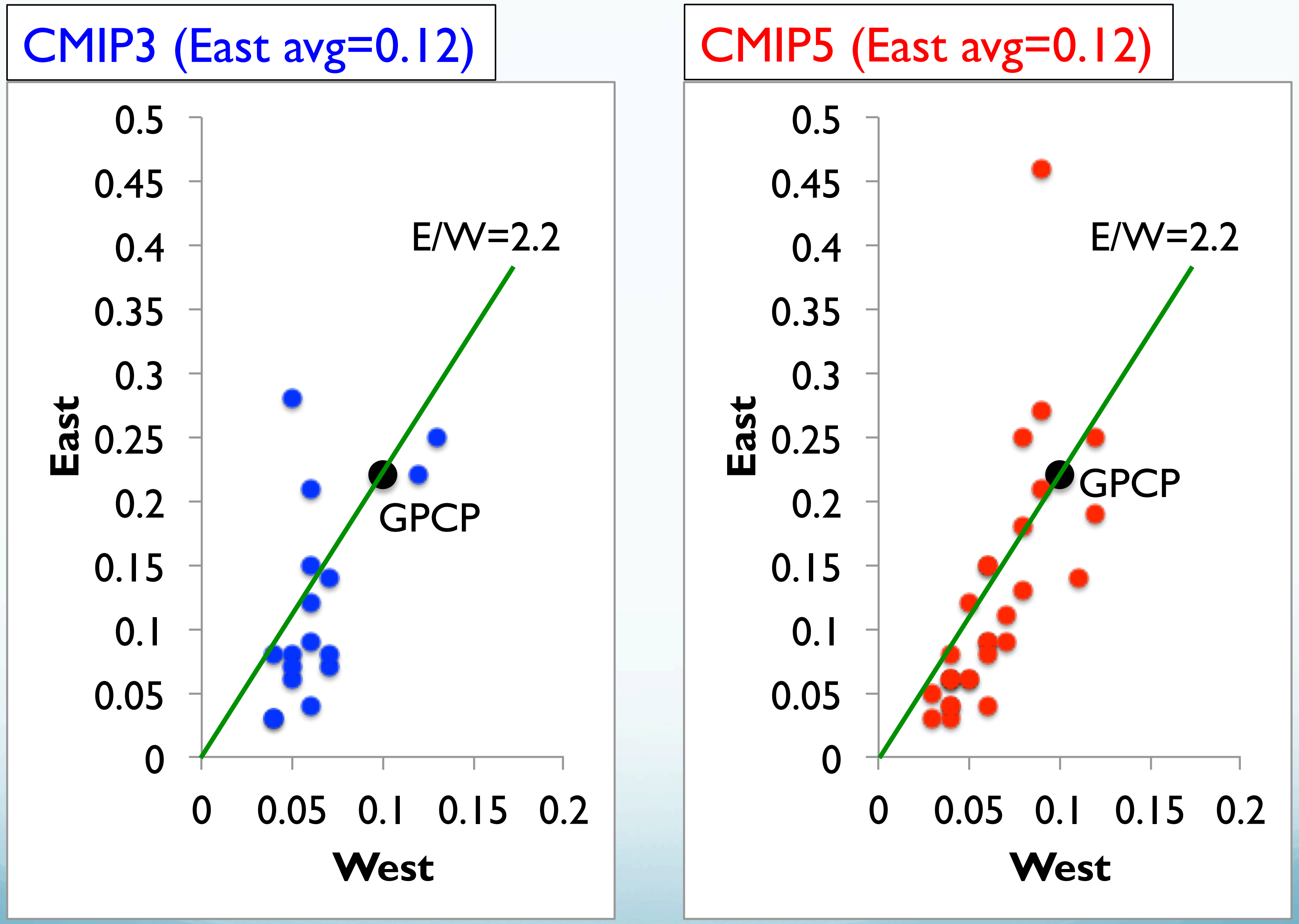
- **East(West)**
  sum of spectral power within box A
  (sum of spectral power within box B)
- **E/W**: East/West
- Wavenumber 1-3, period 30-60 days
- Model data is interpolated into 2.5 x 2.5 degree resolution
- 20-year (1979-1998) period from 20C simulation is used
- GPCP data for 1997-2008 is used as reference

CMIP3 vs. CMIP5 - a glance

East/West ratio
(wavenumber1-3, period 30-60)



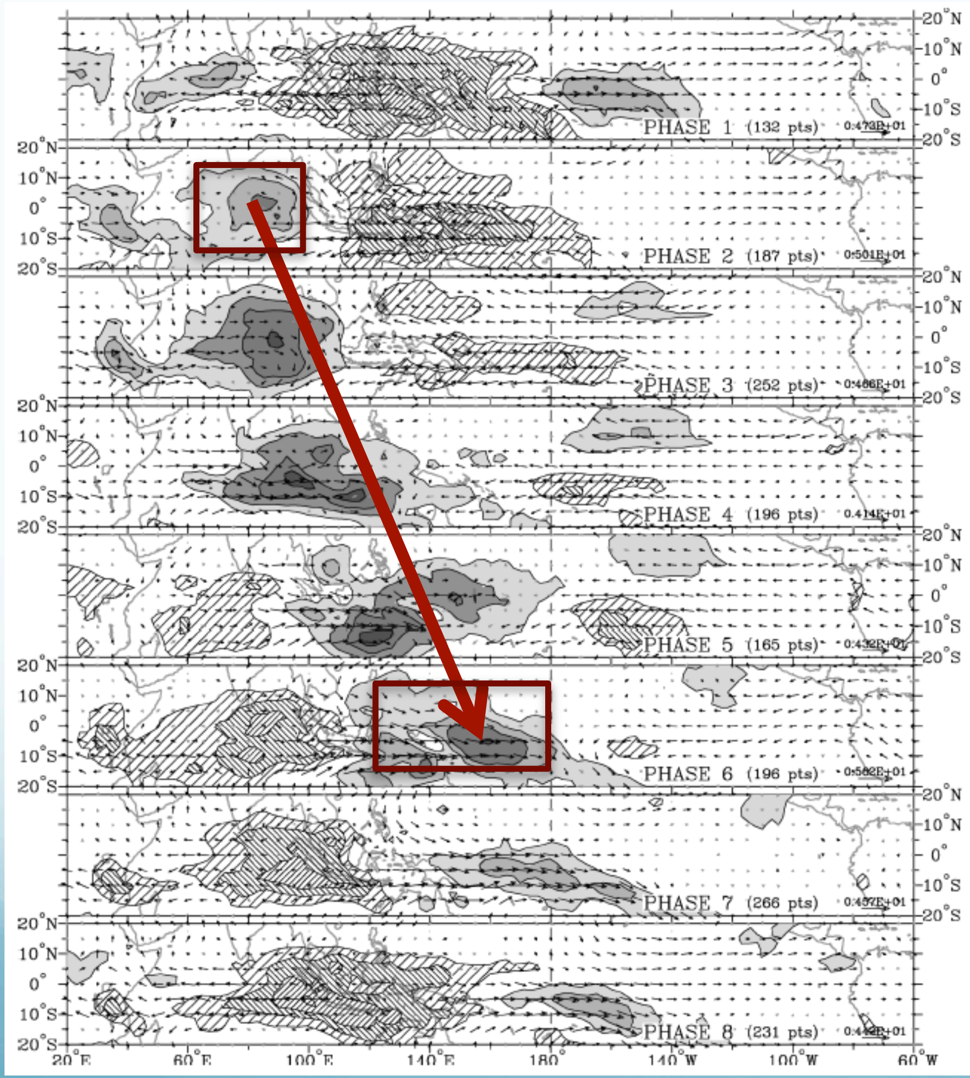
GPCP=2.2



CMIP3 (East avg=0.12)
CMIP5 (East avg=0.12)
East
West
E/W=2.2
GPCP
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.05
0.1
0.15
0.2


Decent MJO
Tell me where to go, then I will run…
CMIP models

“Life-cycle” of the MJO

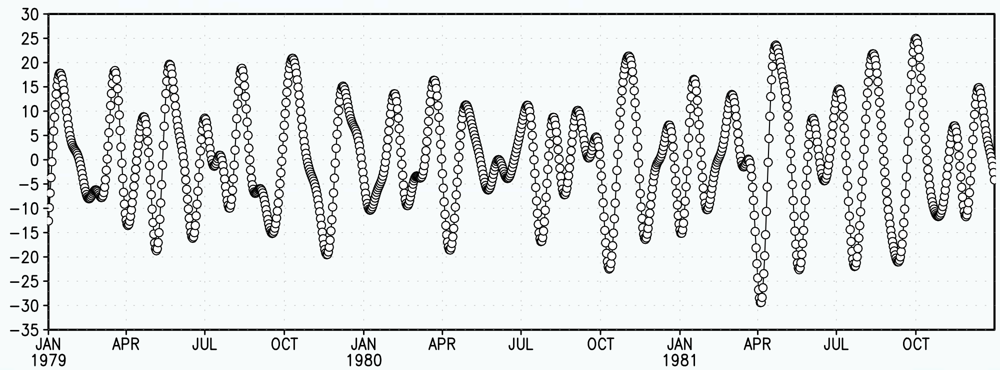


- We here focus on the propagation from the IO to the WP
- Is every IO convection making propagation to the WP? If not, what makes the difference?
- Seek IO convection onset days, examine propagation characteristics of each event

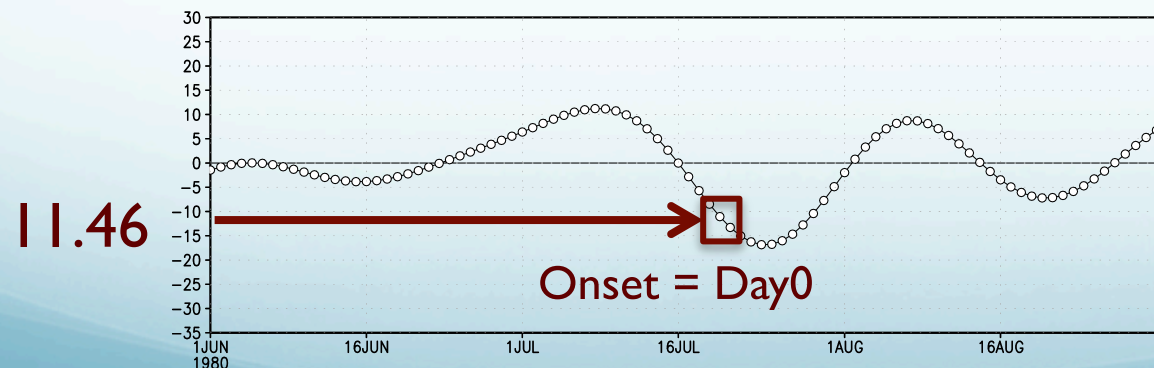
OLR (shaded)
850hPa wind (arrow)
Wheeler and Hendon (2004)

Onset of IO convection

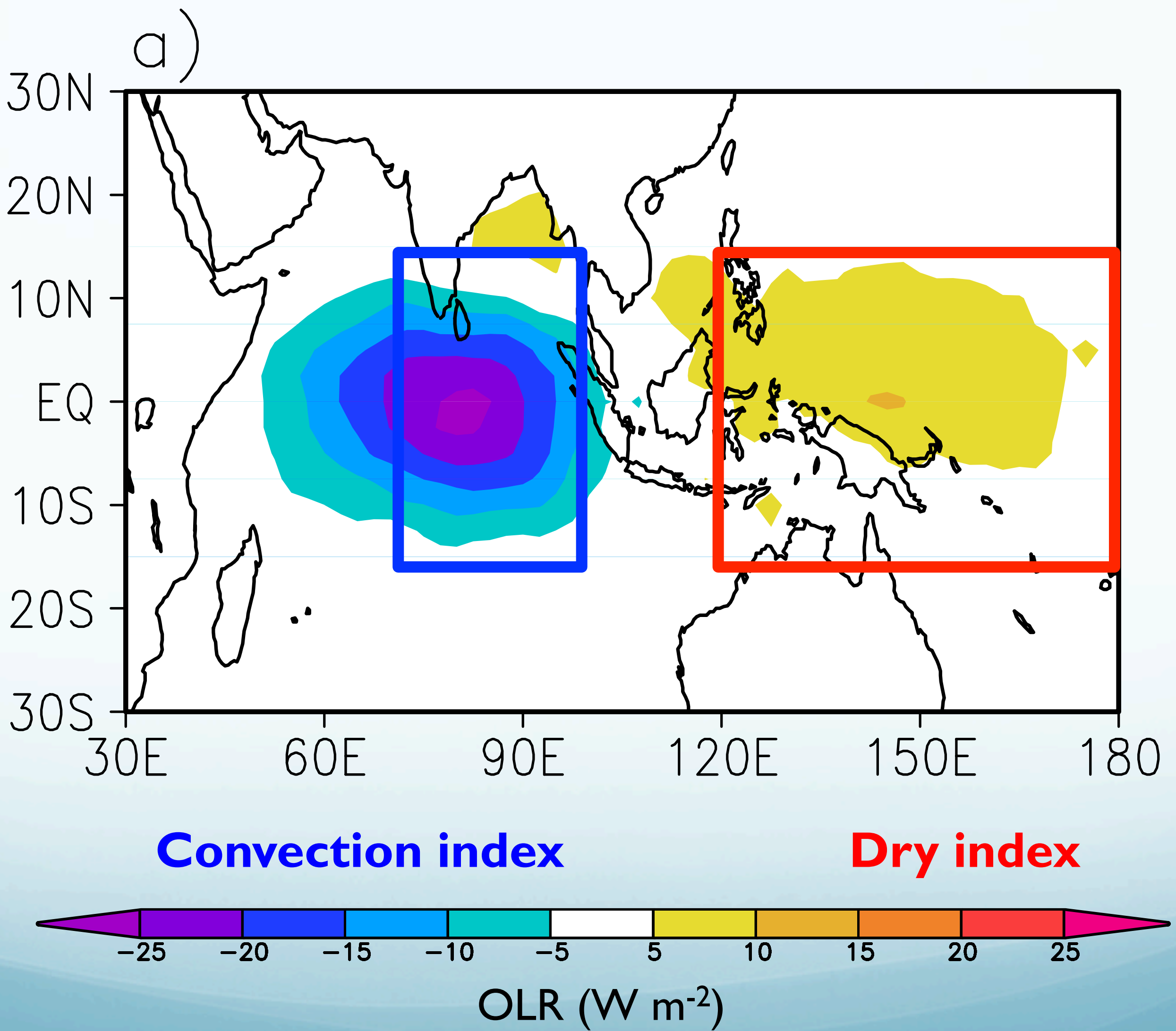
20-100 day filtered OLR anomaly
averaged over the IO (70-100E, 15S-15N)



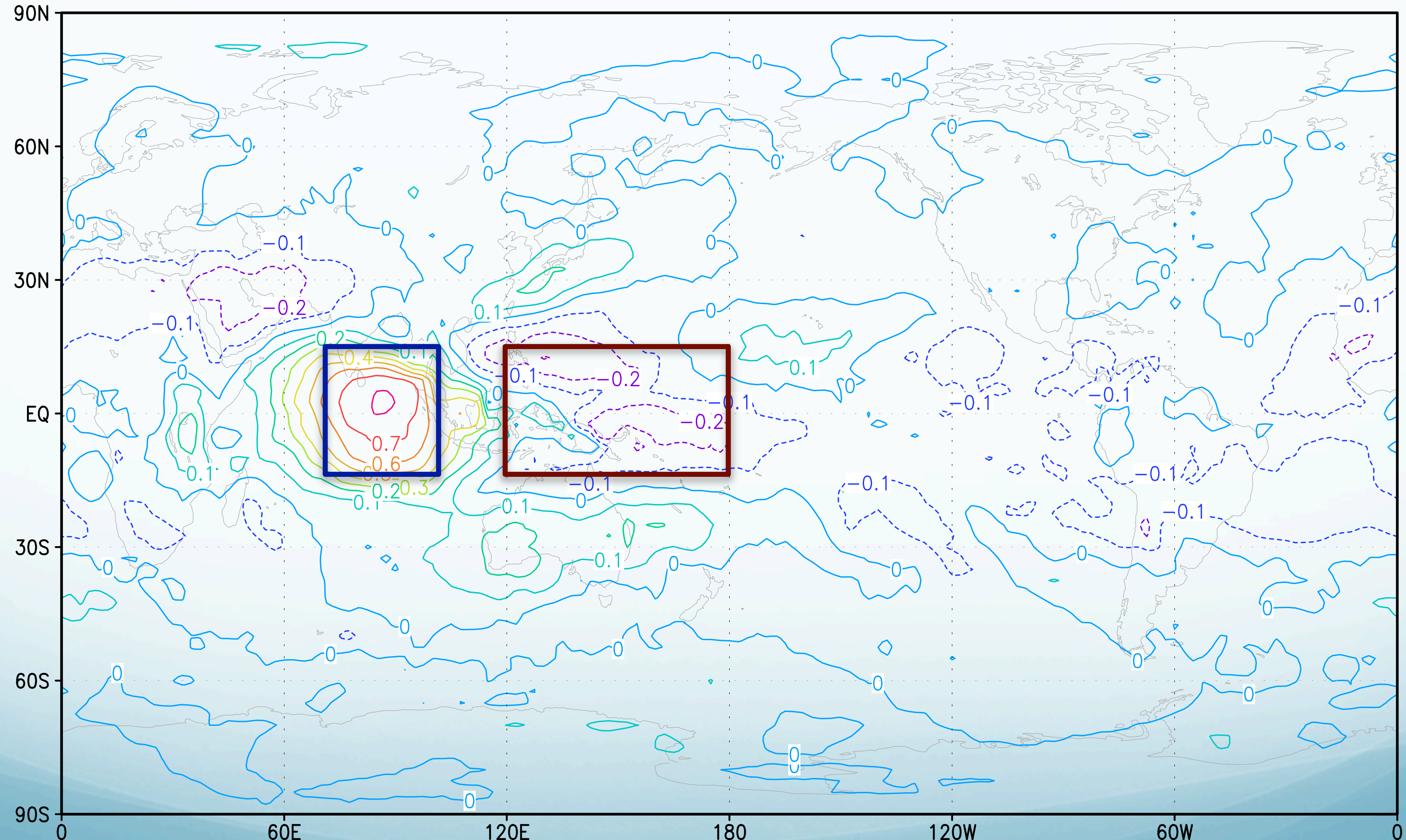
std = 11.46

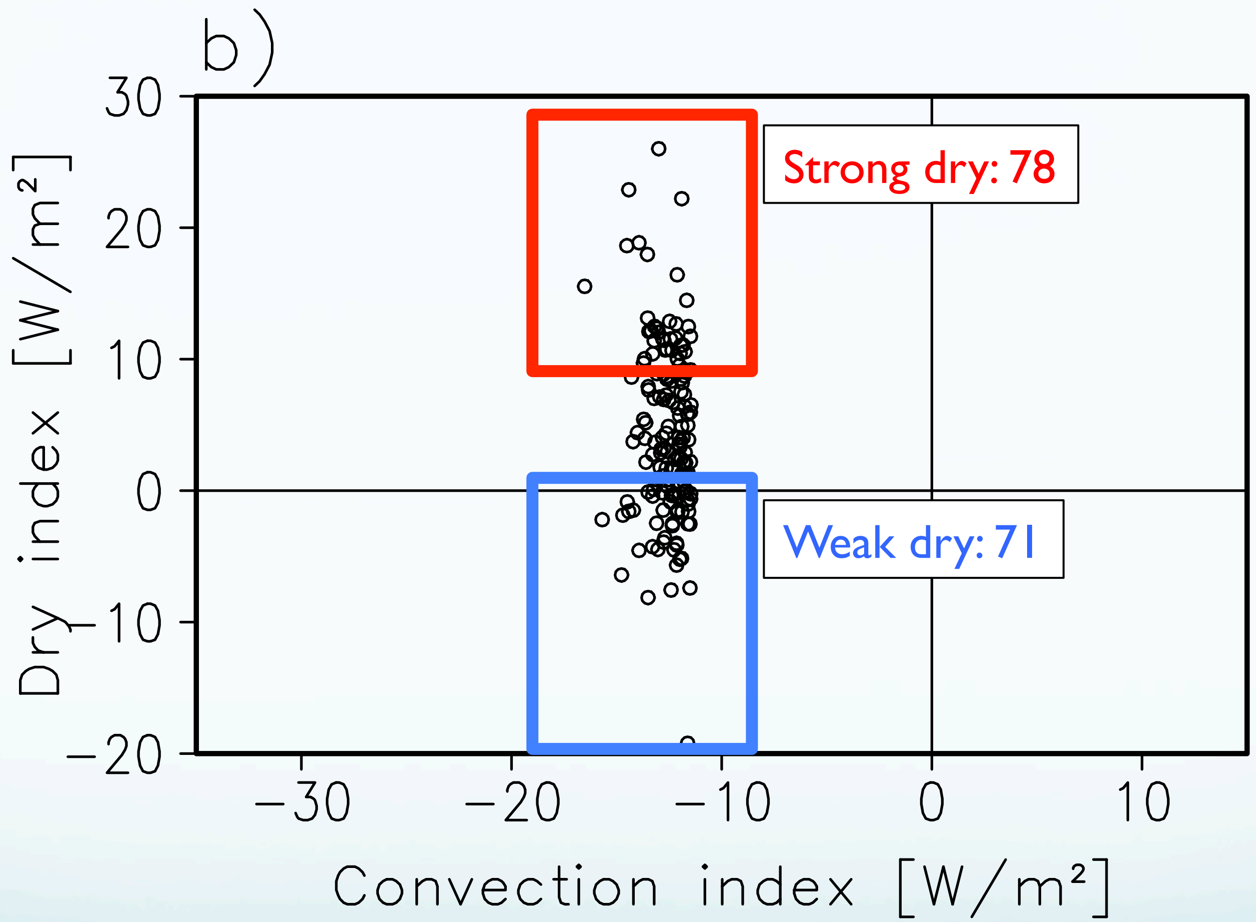


MJO onset over the eastern IO



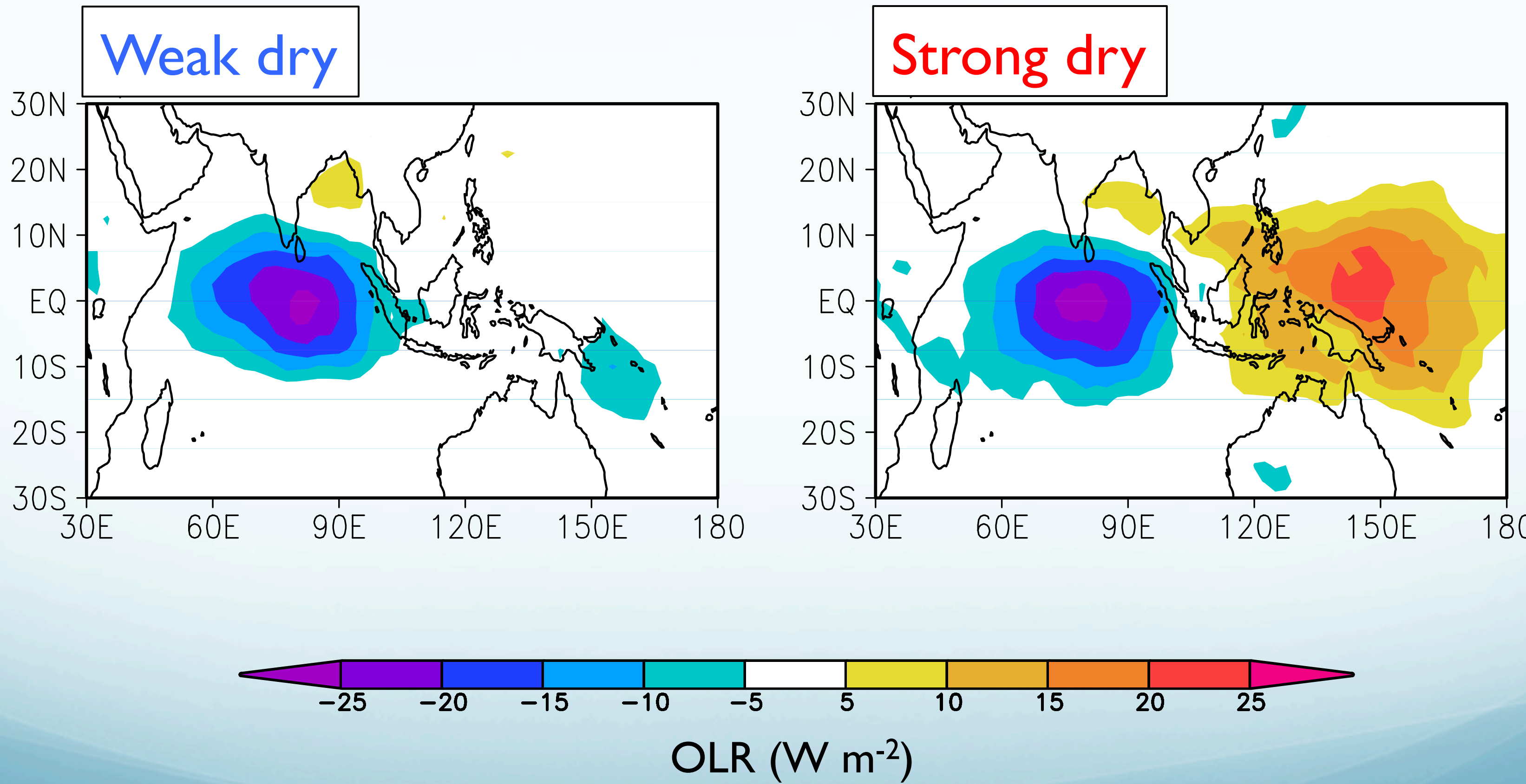
Correlation of 20-100 day filtered OLR anomaly against 70-100E, 15S-15N averaged time series



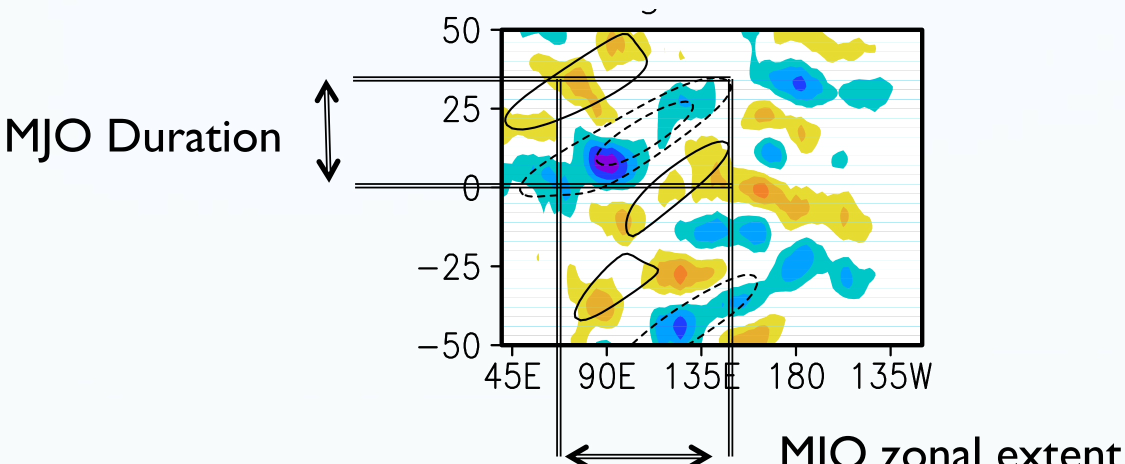


The dry anomaly over the WP doesn't strongly tied to the convection anomaly over the IO

Weak dry vs. Strong dry



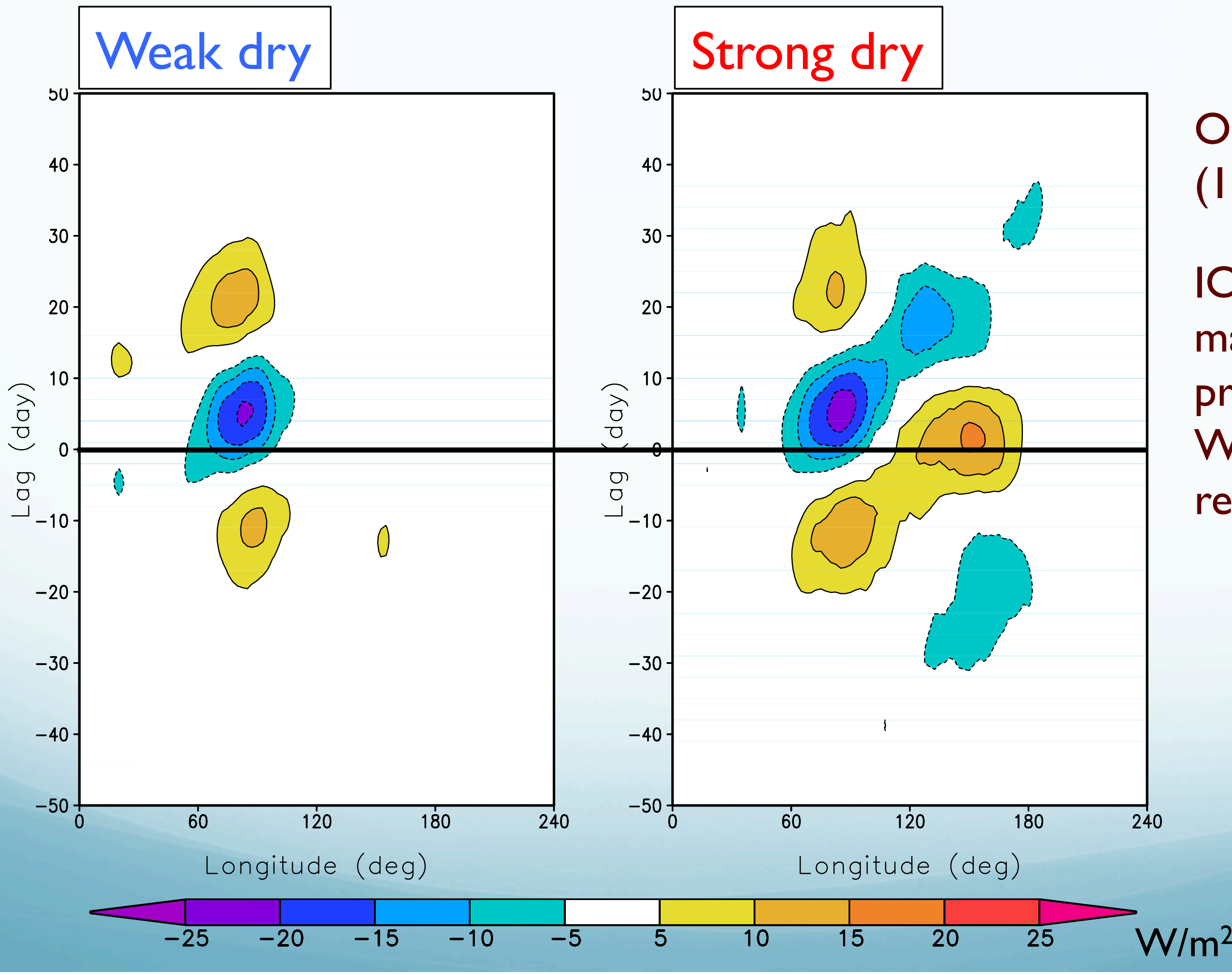
MJO properties



Category	Weak Dry	Strong Dry
Number of MJO events	41 (71)	44 (78)
MJO zonal extent [deg]	33.2	60.2
MJO Duration [day]	18.77	26.34

MJO convection lives longer and propagates further to the east when there is a relatively stronger dry anomaly over the WP

Propagation characteristics



OLR anomaly (10S-10N avg.)

IO convection makes eastward propagation when WP dryness is relatively stronger

Column integrated moist static energy budget

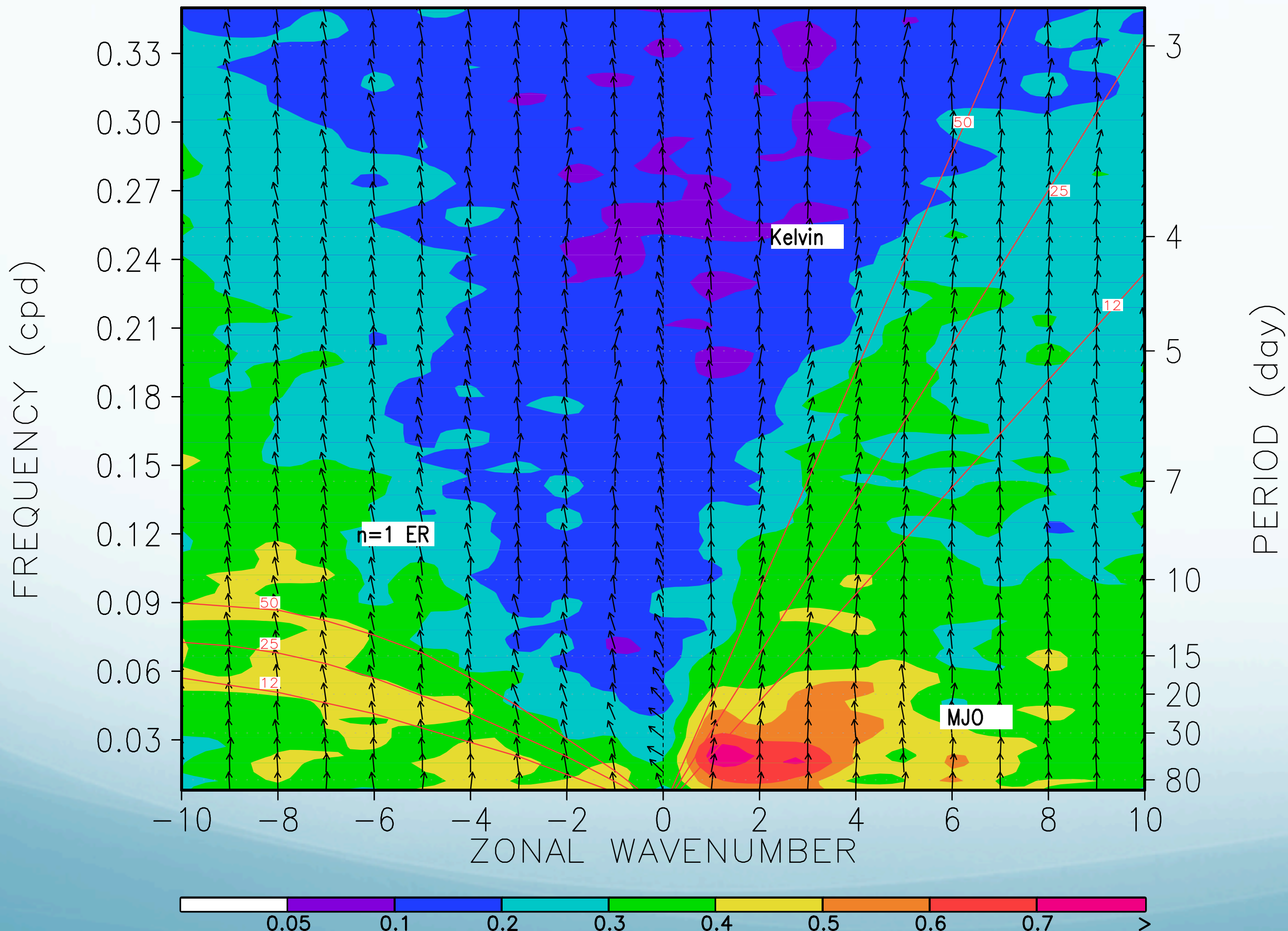
Moist static energy: m = CpT + gz + Lq

$$\underbrace{\left\langle \frac{\partial m}{\partial t} \right\rangle}_{1} = \underbrace{-\left\langle \vec{V} \cdot \nabla m \right\rangle}_{2} \underbrace{- \left\langle \omega \frac{\partial m}{\partial p} \right\rangle}_{3} + \underbrace{LH + SH}_{4} + \underbrace{\langle LW \rangle + \langle SW \rangle}_{5}$$

1. Storage
2. Horizontal advection
3. Vertical advection
4. Surface turbulent fluxes
5. Radiative fluxes

Why MSE budget?

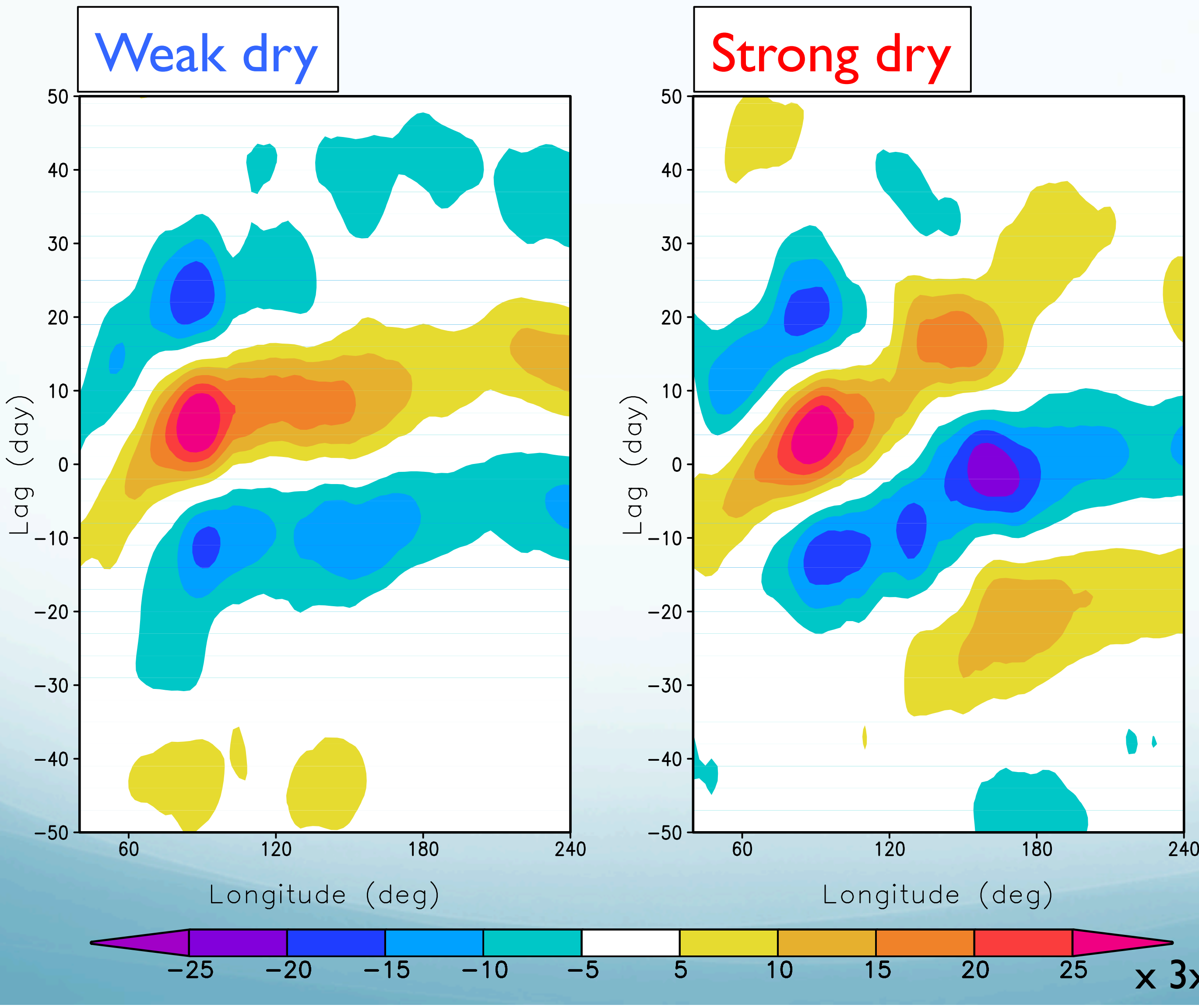
Coherence and phase between <m> and PRCP



In general <MSE> and PRCP anomalies are in-phase.

MJO is distinguished from other waves by the strong coherence between <m> and PRCP

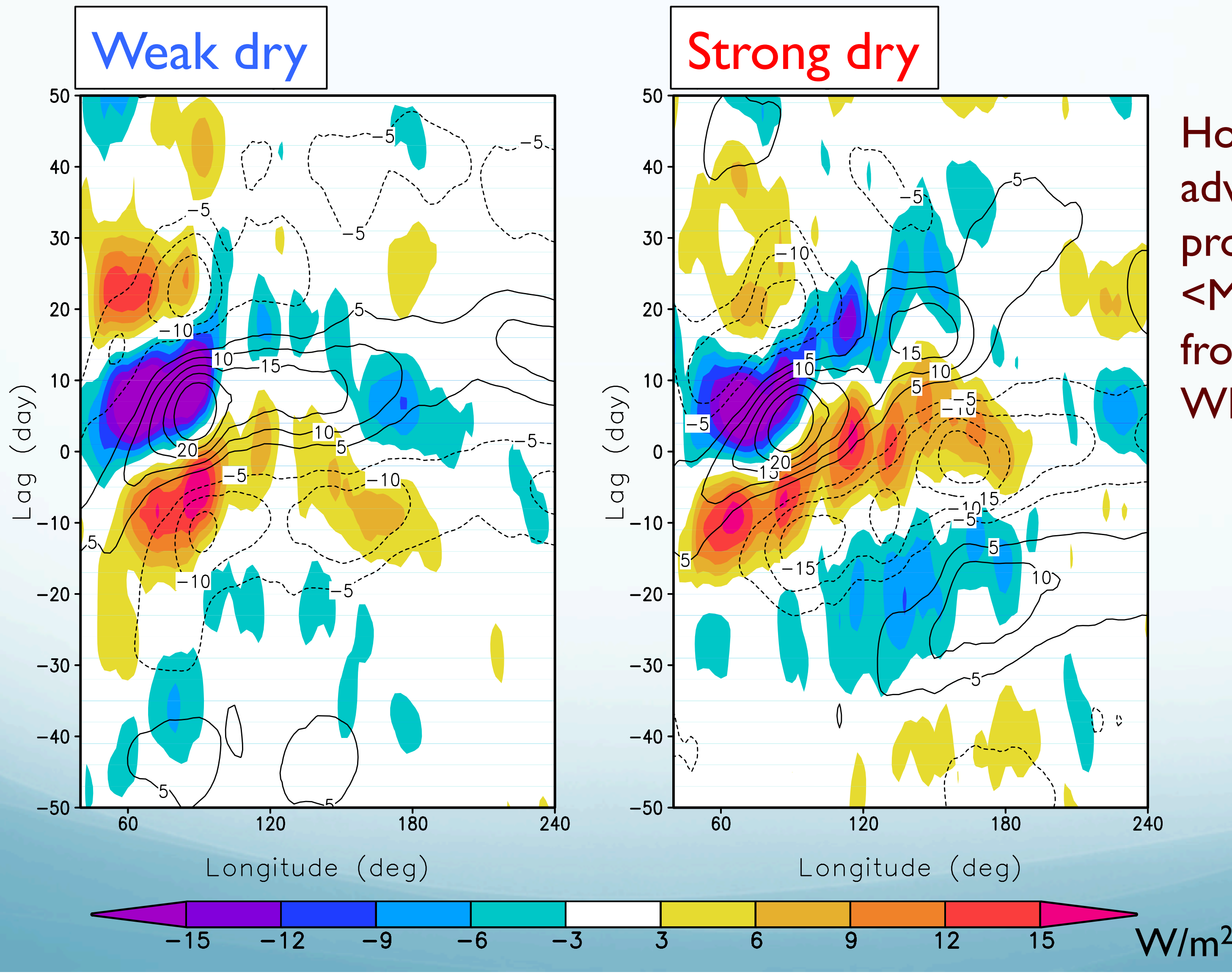
Propagation of <MSE>



<m> anomaly (10S-10N avg.)

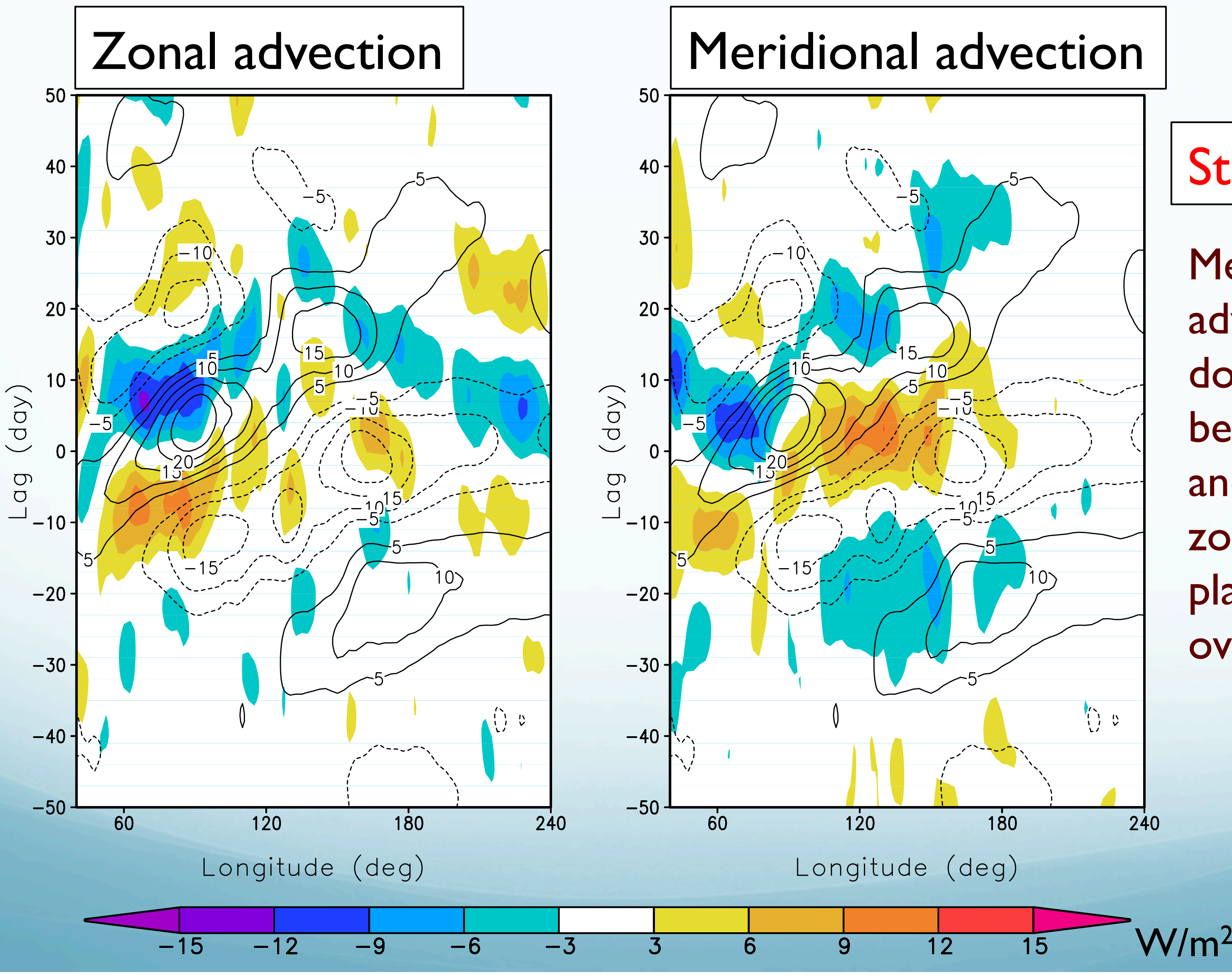
Consistent with that of OLR anomaly

<Horizontal advection of MSE>



Horizontal advection leads propagation of <MSE>, especially from the IO to the WP

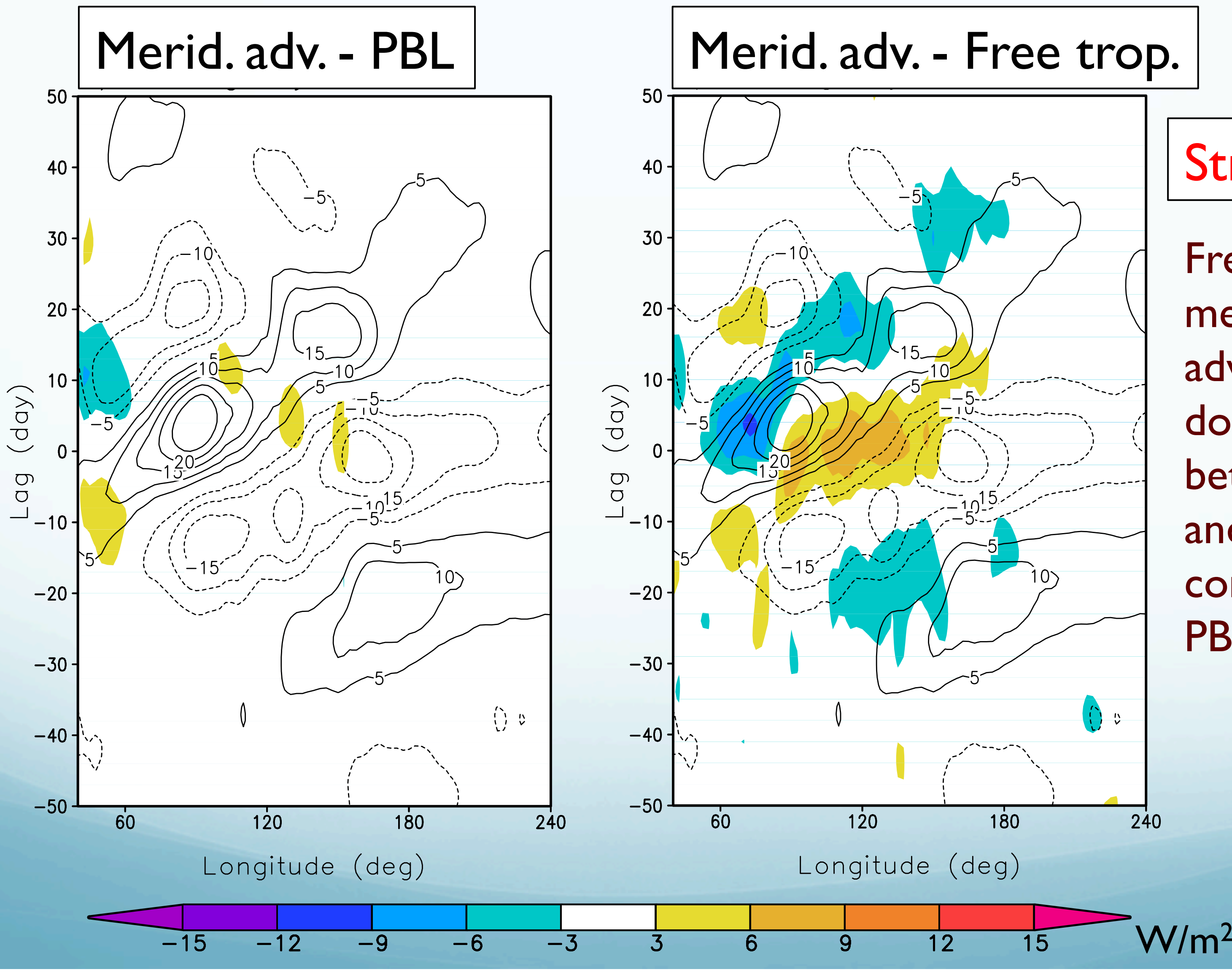
Zonal vs. Meridional Advection



Strong dry

Meridional advection dominates in between the IO and the WP, while zonal advection plays a bigger role over the IO

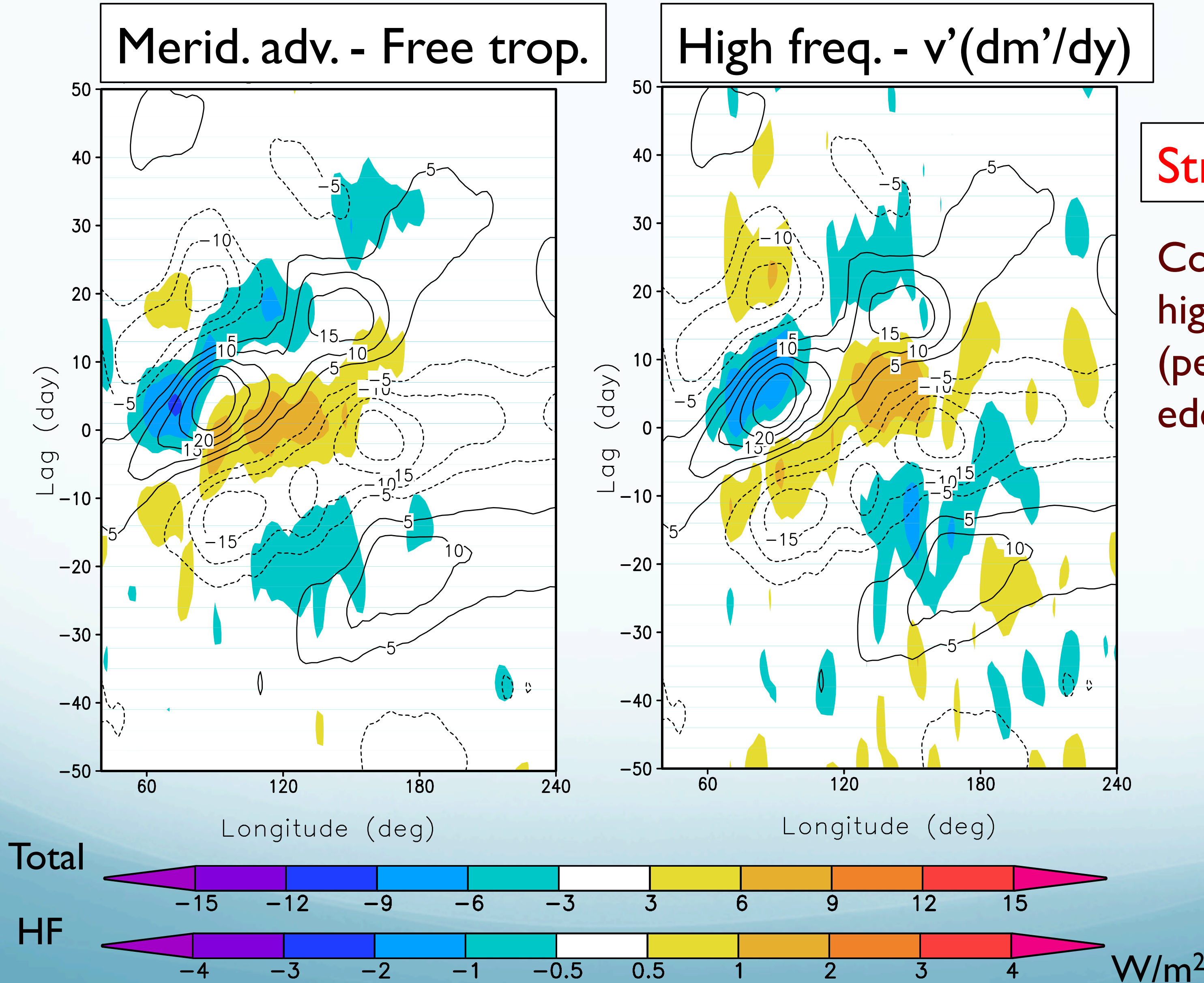
PBL vs. Free Troposphere



Strong dry

Free tropospheric meridional advection dominates in between the IO and the WP, while contribution from PBL is minor

Role of high-frequency eddies

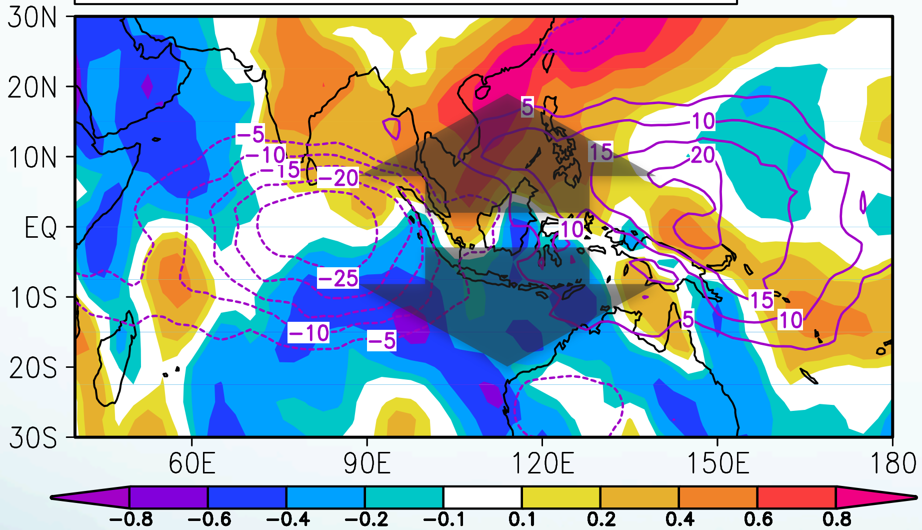


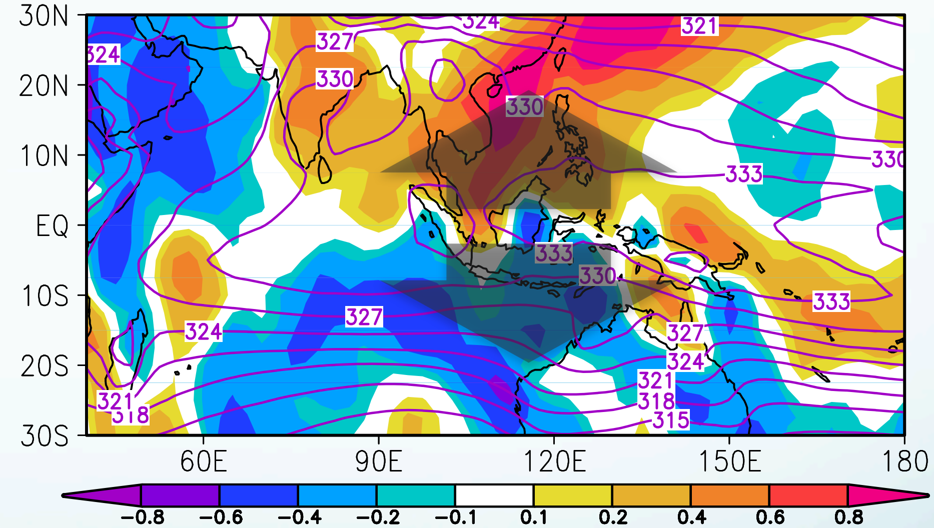
Strong dry

Contribution from high-frequency (period<10days) eddies is minor

Role of poleward flow in front of convection

Strong dry (Day0-4 avg)

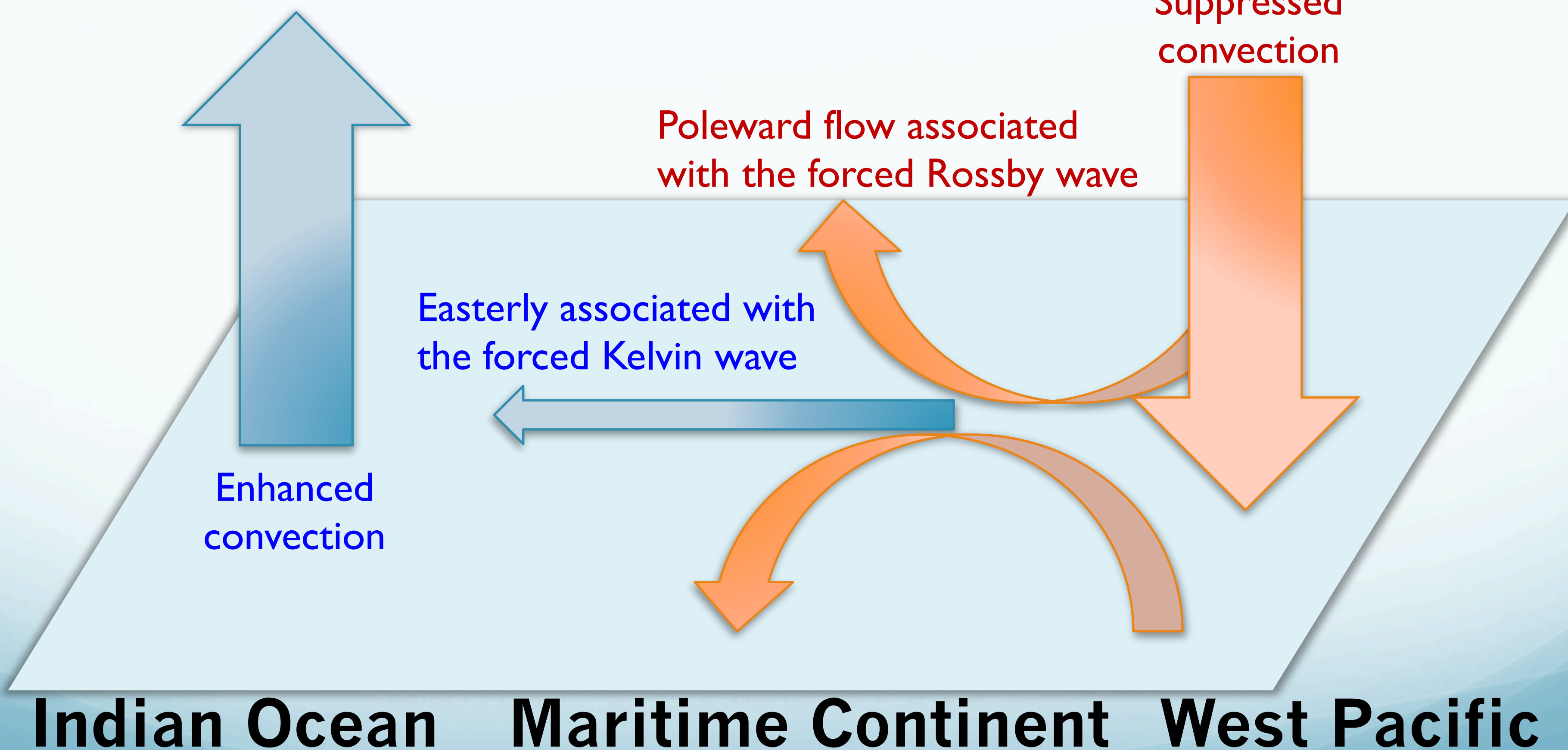




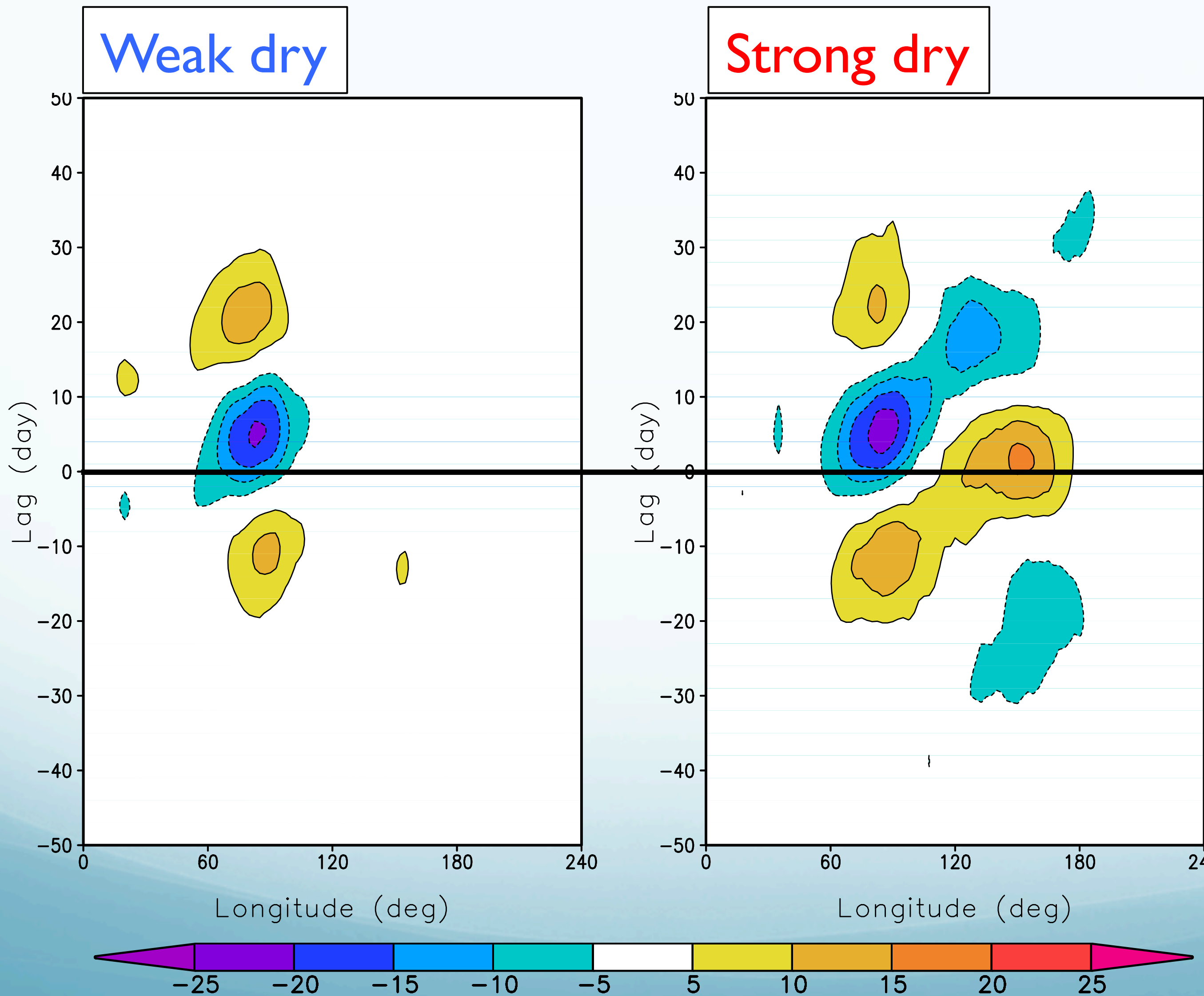
Shaded: v anomaly
Contour: OLR anomaly

Shaded: v anomaly
Contour: mean MSE

Schematic view



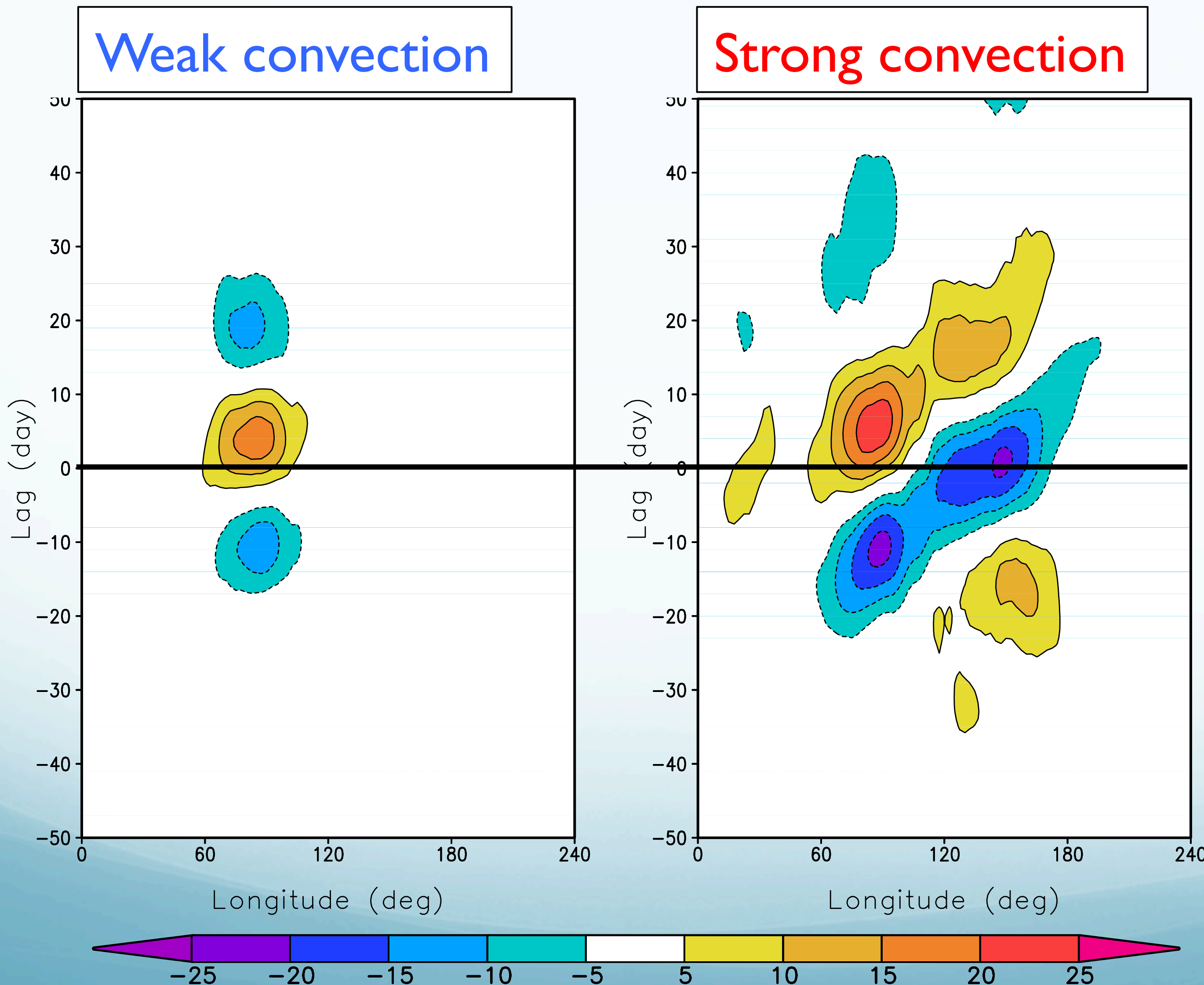
Initiation mechanism



IO convection makes eastward propagation when WP dryness is relatively stronger

The WP dry is a result of eastward propagating dry anomaly from the IO

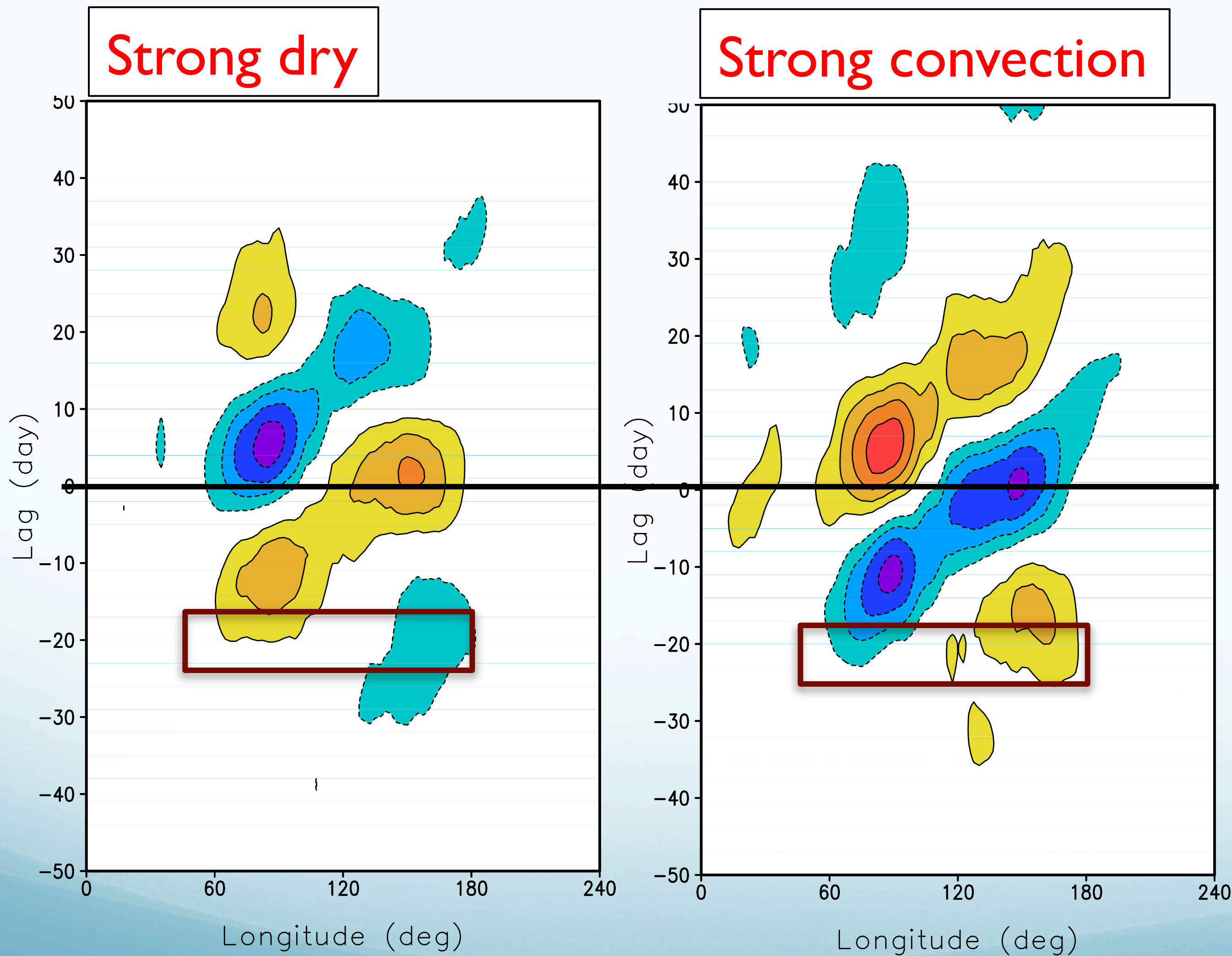
Initiation mechanism



IO dry anomaly makes eastward propagation when WP convection is relatively stronger

The WP convection is a result of eastward propagating convection from the IO

Initiation mechanism



A hypothesis:

The propagation of the IO convection/ dry to the WP occurs when the dipole structure has made by previous MJO event, or by chance.

Summary

- Associated with the MJO, the planetary-scale convective anomaly over the Indian Ocean (IO) usually propagates eastward and reach the west Pacific (WP), but not always.
- All 189 IO convection onset events are classified into three categories based on the strength of the dry anomaly over the WP.
- The IO convection anomaly lives longer, and makes a further propagation to the east when the dry anomaly is relatively stronger. When the dry anomaly is relatively weaker, the convection anomaly ceases before reach the WP in most cases.
- Meridional advection of <m> in the free troposphere plays an important role on the propagation of IO convection. Contributions from PBL, and high-frequency eddy are minor.
- The dry anomaly plays a dynamically active role on the propagation of the IO convection through the Rossby response to it, which enhances meridional advection of <m> in front of the convection anomaly by inducing poleward flow.